Friday, April 27, 2012

Reading: Chapters 11 (omit 11.6), 12, 13, 14

Fifth Exam, Friday, May 4

Fifth sky watch due. You can do any object mentioned throughout the term that you have not done before.

Electronic class evaluations. Please respond. This feedback is very valuable to me and to the TAs.

Astronomy in the news?

News:

1 American astronaut and 2 Russian cosmonauts just landed in Kazakhstan after 5.5 months on the International Space Station.

Goal:

To understand how string theory represents the current best candidate to be the needed theory of quantum gravity (Chapter 14)

Need quantum gravity theory of singularity, quantum foam, worm holes

The best current candidate for a theory of Quantum Gravity is String Theory

See Brian Greene - The Elegant Universe

(http://www.pbs.org/wgbh/nova/elegant/)

Read ***The Universe on a String*** editorial by Brian Greene posted under links -> string theory

Hyperspace is an intrinsic aspect of string theory - 10 dimensions of space, plus time.

Background - pre-Einstein late 19th, early 20th Century

Where does space curve to?

Riemann (1826 -1866), Lobachevsky (1792 - 1856)

Theory of curved space, non-Euclidian geometry

Notions of 4D hyperspace affected art/culture turn of 20th century

Flatland - Edward Abbott (recent films)

Tesseract - 4D hypercube (Elegant Universe link)

3D “unfolding” of tesseract in Salvadore Dali’s

Crucifixion (Corpus Hypercubas)

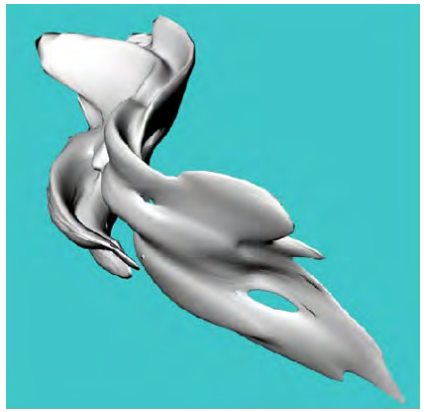
Notions of seeing from different directions at once

Perspective of Cubism

Picasso - Les Demoiselles d'Avignon

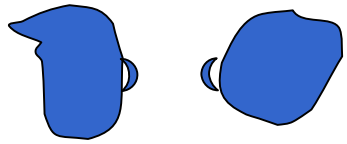
Duchamp - *Nude Descending A Staircase*

Contemporary Greek-American artist Marcos Novak - 3D projections of 4D objects



Hyperspace Perspectives (reflected in cubism?)

2D creature - another 2D creature sees the front



From 3D, we see front, back and ***inside*** simultaneously

In our 3D space we see the front of another 3D creature

A being living in a 4D hyperspace would see all of our surface, front and back, and our insides, all at once!

A 3D creature passing through a 2D Universe would start as a point, grow to a finite ***area***, then decrease to a point and disappear.

A 4D creature passing through our 3D Universe would start as a point, grow to a finite ***volume***, then decrease to a point and disappear.

Sagan YouTube

Living and perceiving different dimensions

http://www.youtube.com/watch?v=Y9KT4M7kiSw

Nota Bene: even if hyperspace exists, that does not mean it is populated with living creatures, that notion is just to help us gain perspective.

One Minute Exam

A five-dimensional creature intruding into our space would appear to us to be

 One-dimensional

 Two-dimensional

 Three-dimensional

 Four-dimensional

Classic Quantum Theory

Particles are points (electrons) or are made up of point-like particles (three quarks in a proton or neutron), that also have wave-like properties.

Quantum view of forces - the quantum theory (mathematically) views all forces as resulting from an exchange of particles, with different exchange particles representing different forces.

Photons are the exchange particles for the electromagnetic force, other exchange particles account for the weak and strong nuclear forces.

String Theory

Best current candidate for a quantum gravity "theory of everything."

String theory is a quantum theory, but it also intrinsically contains curved surfaces.

Particles like e-, p, n are not "points" but strings, otherwise identical loops of energy that vibrate in different modes

The different modes of vibrations give all the well-known particles and ***more***

String Theory

History - in 1960's physicists recognized that the equations corresponding to the strong nuclear force also described entities that could stretch and wiggle - strings

Space in which strings vibrate has ***10 space dimensions*** + time

Shape of wrapped-up space determines how strings vibrate, what particles they represent.

Can't make notes with grains of sand, but with strings, you have Mozart

From Brian Greene - The Elegant Universe

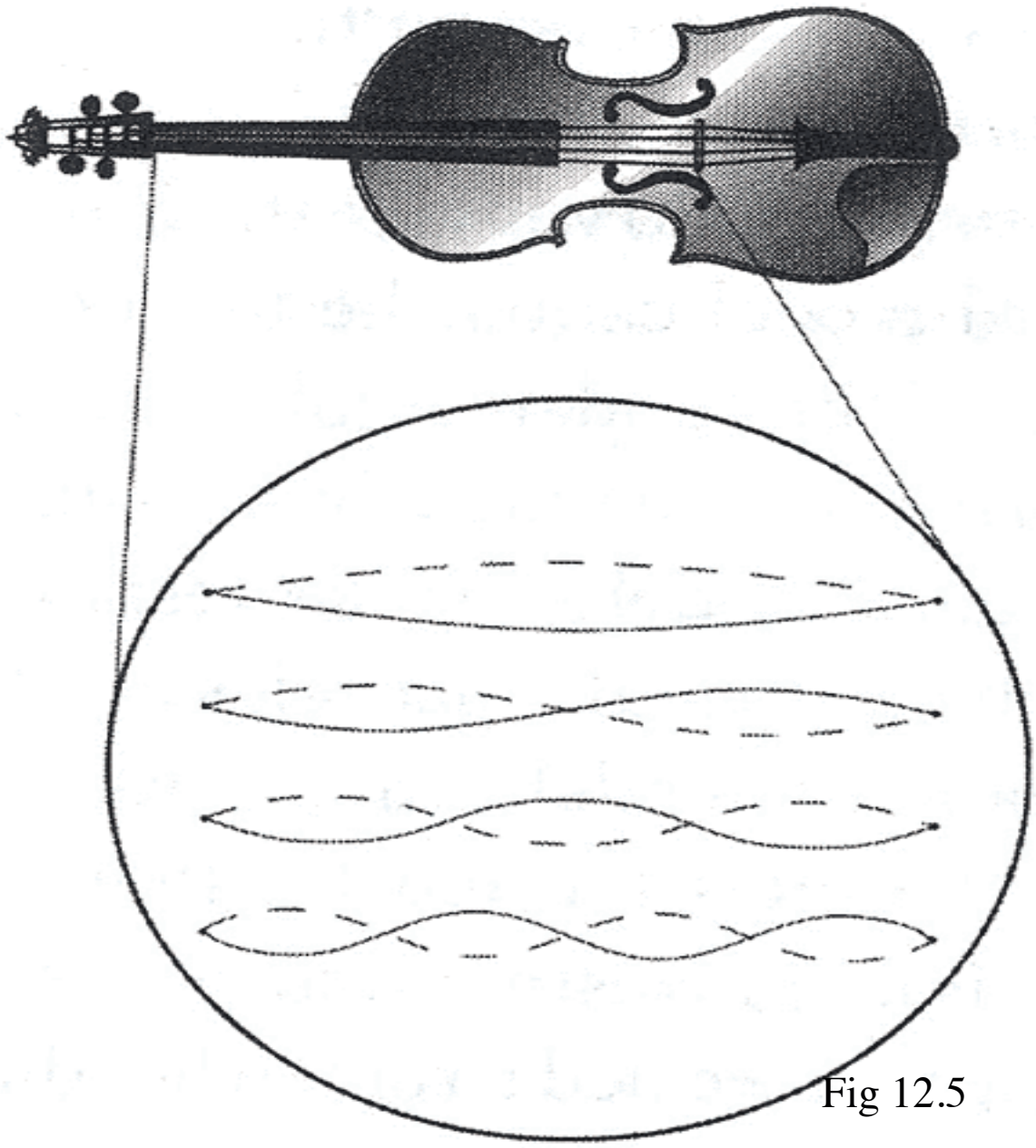
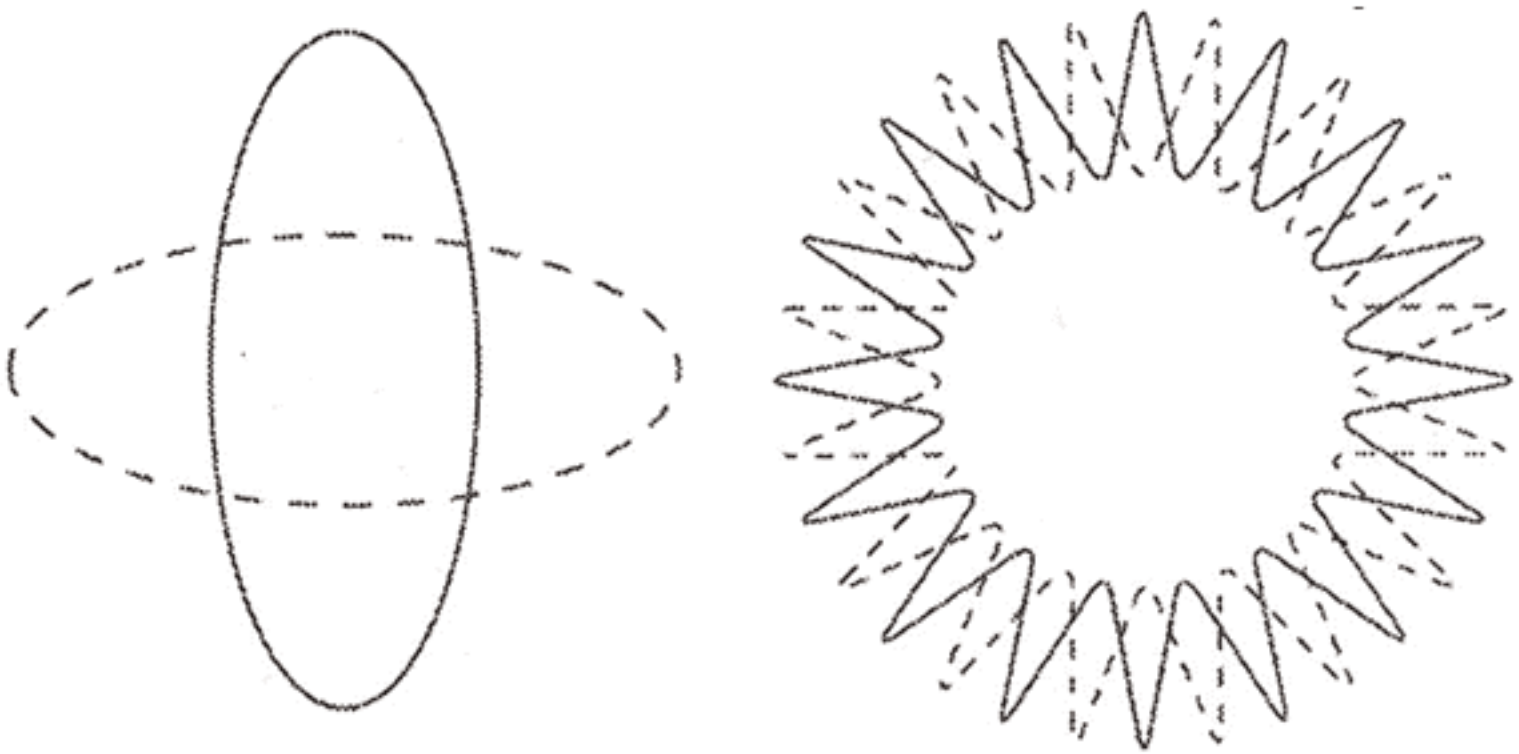


Fig 12.5

One particle

A different particle



Same fundamental loop of string

From Brian Greene - The Elegant Universe

To be mathematically self-consistent

Space in which strings vibrate has ***10 space dimensions*** + time

First notions:

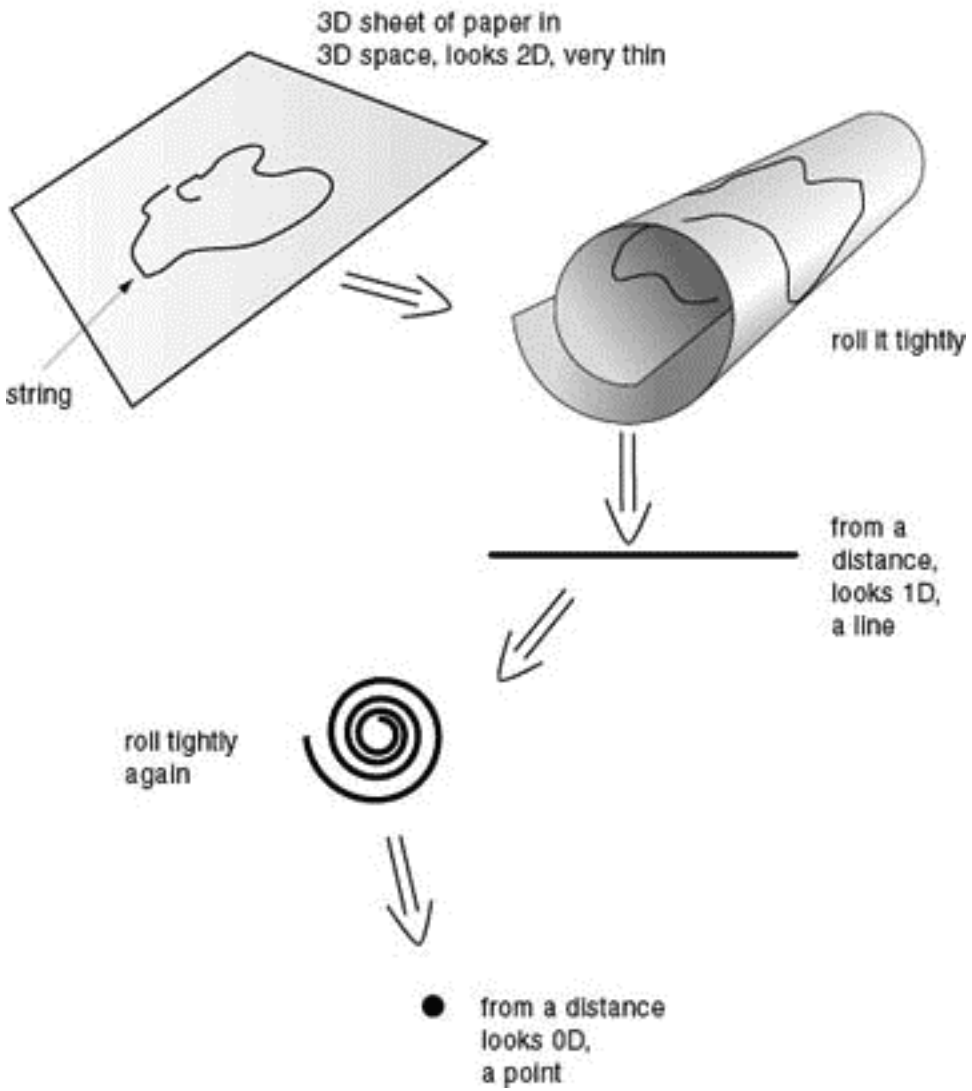
3 big space dimensions + time

Other 7 dimensions "wrapped up" on "string length scale," not known precisely, somewhat larger than the Planck scale, but very tiny so we cannot easily "see."

Dimensions of rubber band, sheet of paper.

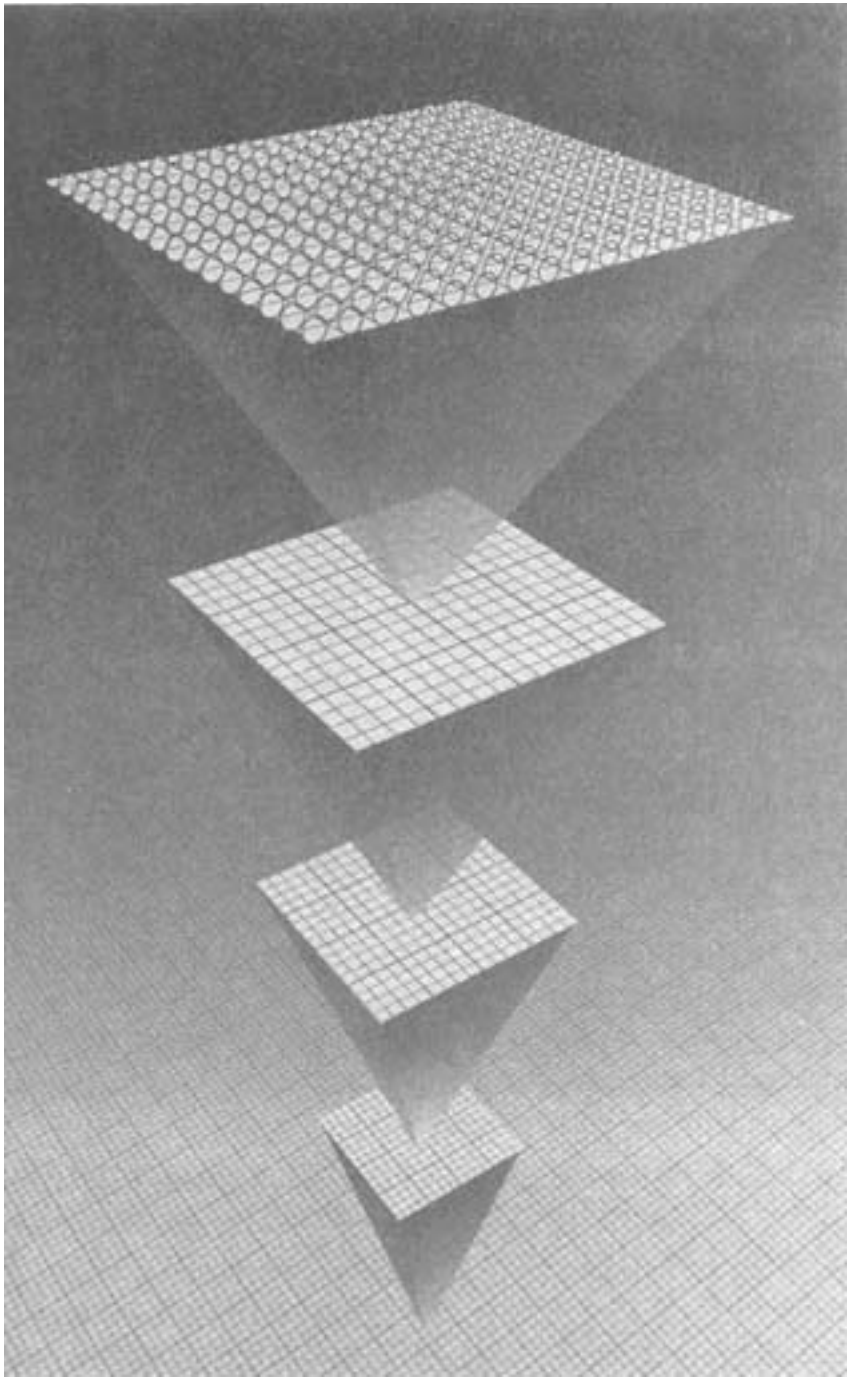
Rubber band - 1D, paper - 2D (wrap rubber band in paper, make 1D, 0D spaces still containing the rubber band)

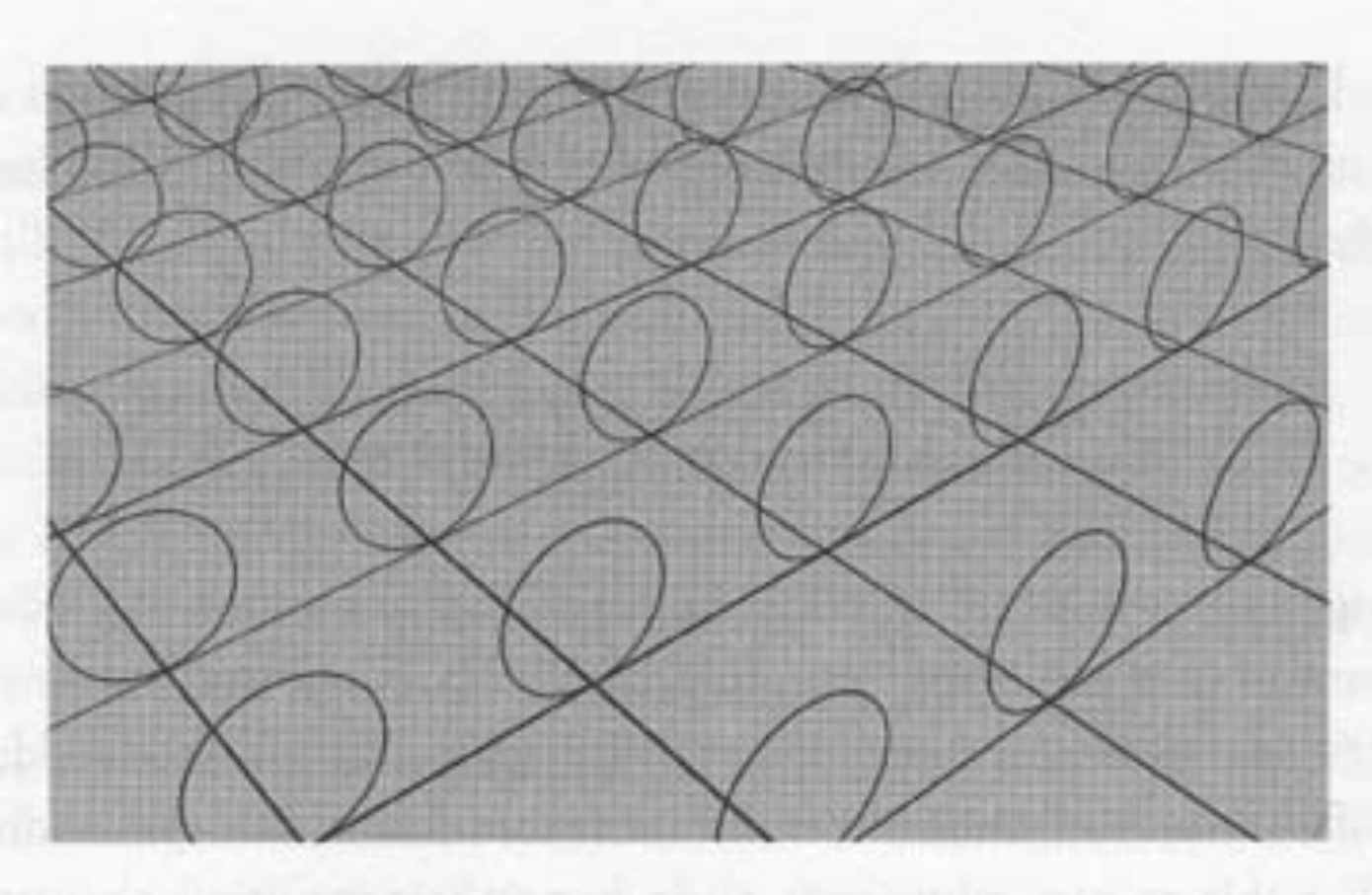
Fig 12.3


3D sheet of paper in
3D space, looks 2D, very thin
string
roll it tightly
from a
distance,
looks 1D,
a line
roll tightly
again
from a distance
looks 0D,
a point

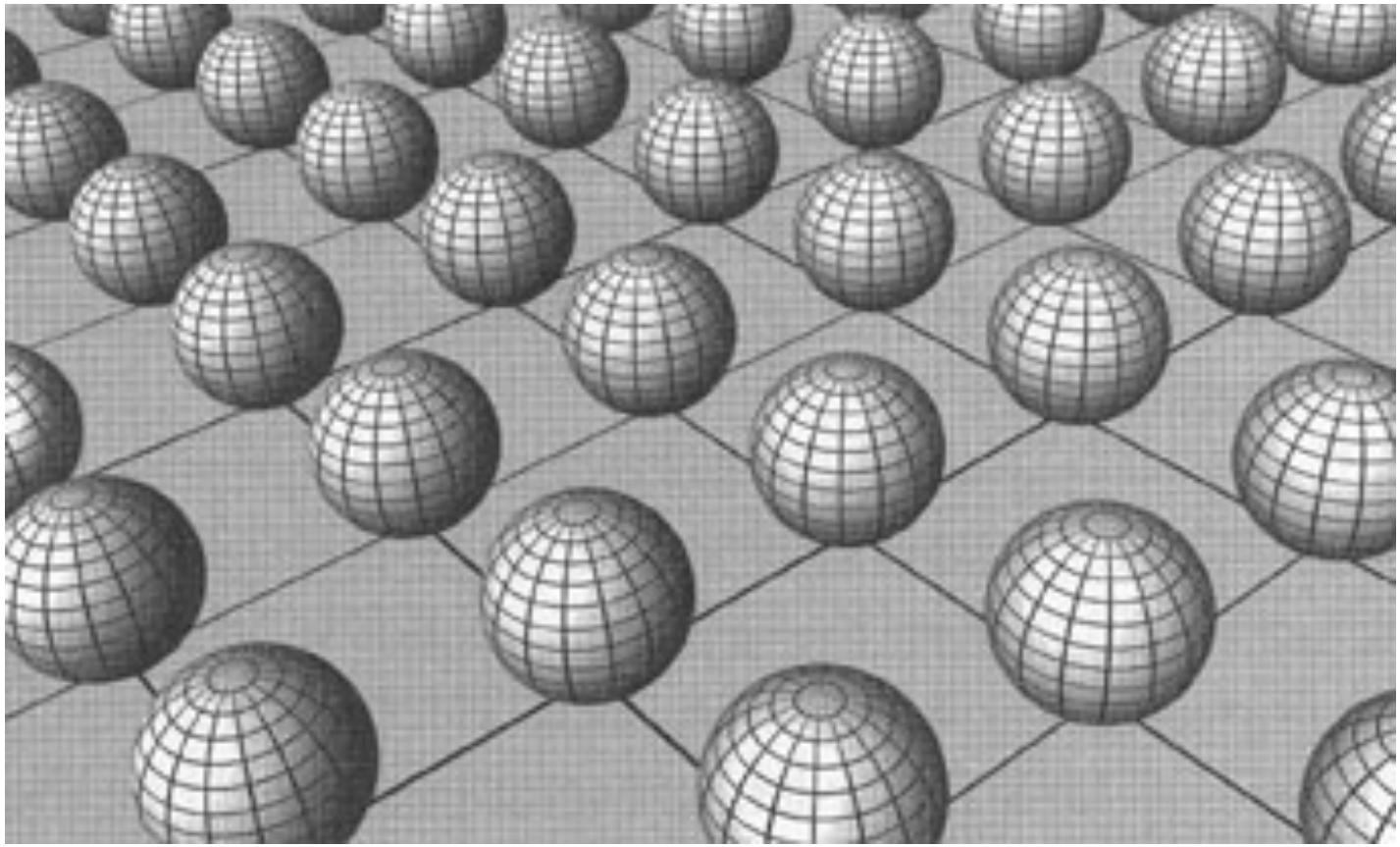
Schematic illustrations of how tiny “wrapped up” extra dimensions could be associated with our 3D space - something like an embedding diagram of the higher dimensional space, so our 3D space is reduced to 2D and the higher dimensional wrapped spaces are reduced to 3D.

From Brian Greene - The Elegant Universe

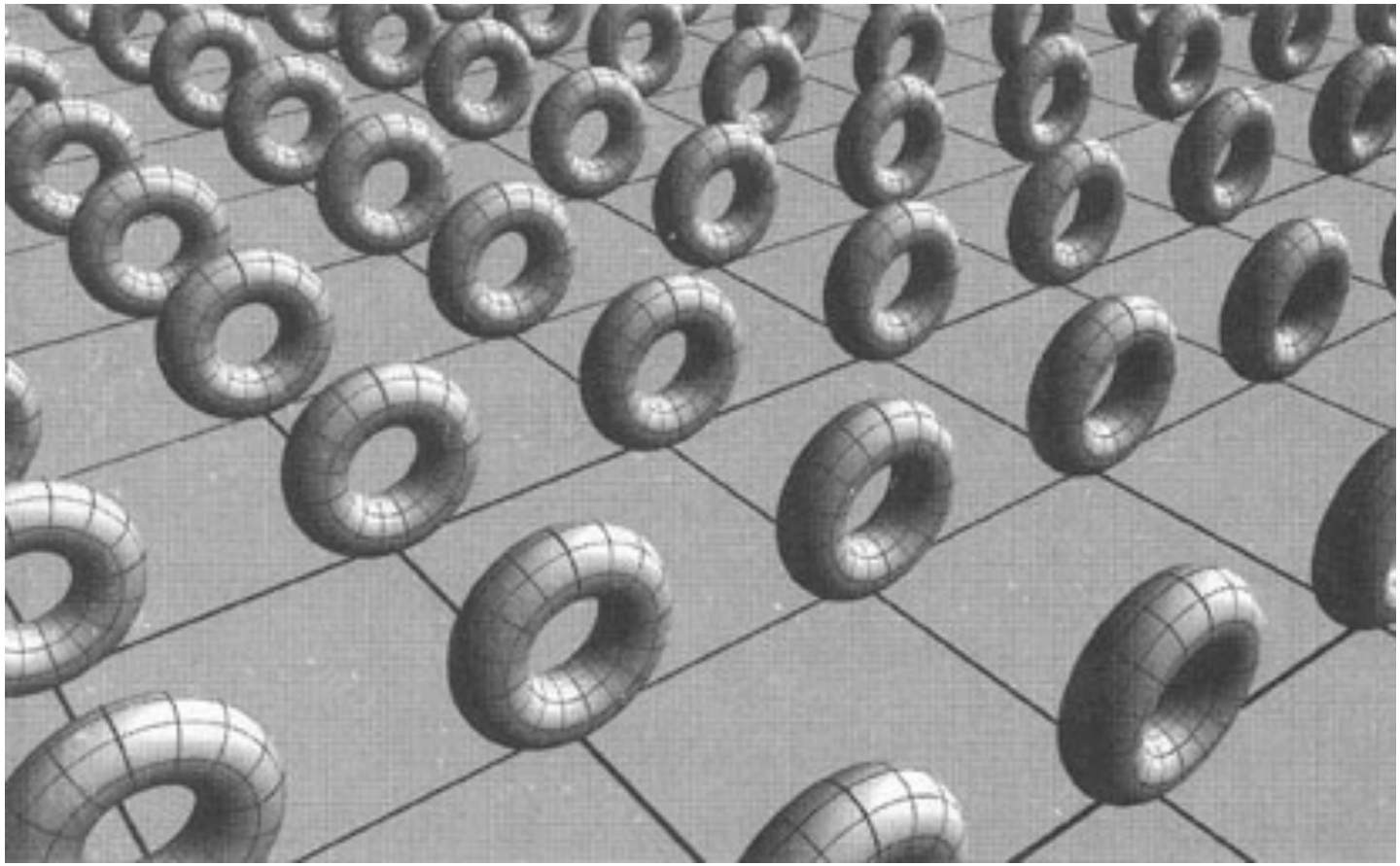




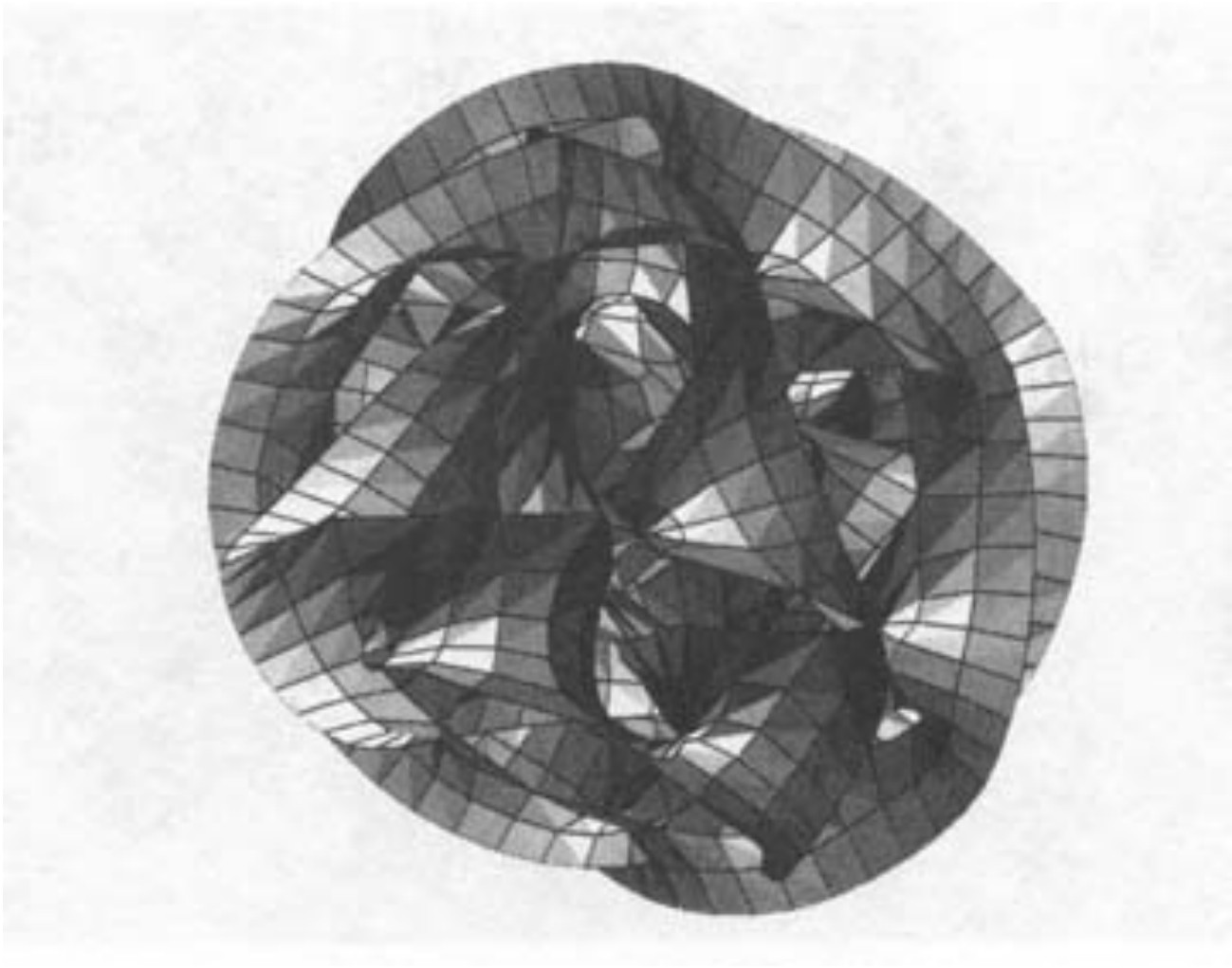
At each point in the 2D space (not just at the intersections of grid lines), there is a little 1D loop of one wrapped up extra dimension. From Brian Greene:The Elegant Universe



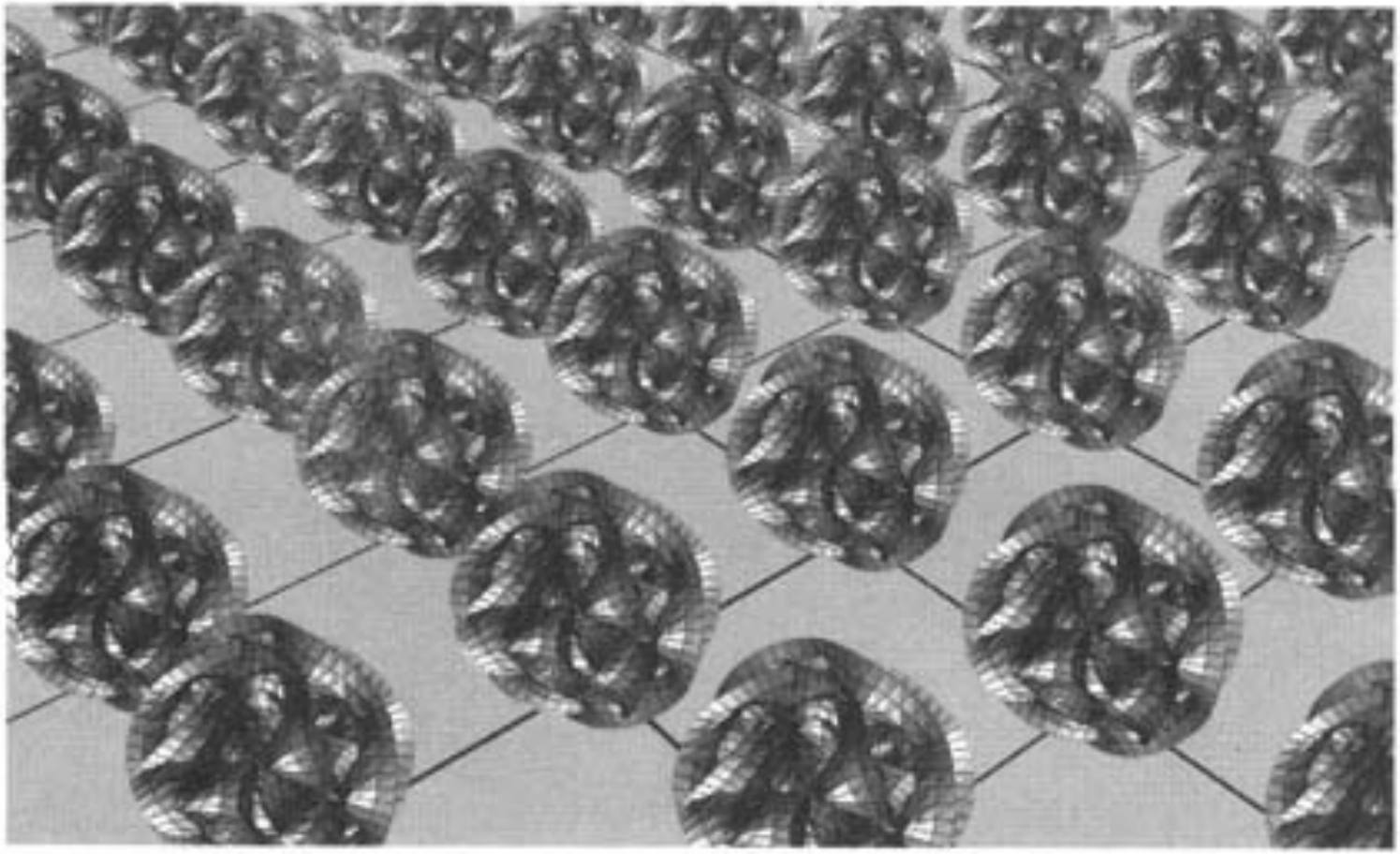
At each point in the 2D space (not just at the intersections of grid lines), there is a little 2D "sphere" of two wrapped-up extra dimensions. From Brian Greene: The Elegant Universe.



At each point in the 2D space (not just at the intersections of grid lines), there is a little 2D “torus” of two wrapped-up extra dimensions. A torus has a distinctly different “topology” or “connectedness” than a sphere. From Brian Greene: The Elegant Universe.



Representation of a Calabi-Yau space, with 6 wrapped-up extra dimensions. Calibi-Yau space gives string vibrations the properties of known particles. From Brian Greene: The Elegant Universe.



At each point in the 2D space (not just at the intersections of grid lines), there is a little 6D Calibi-Yau space of six wrapped-up extra dimensions.
From Brian Greene: The Elegant Universe.

Mathematics of string theory is complex.

Only approximate solutions so far, but:

String theory "contains" Einstein's Theory mathematically on large enough spatial scales that string "loops" are tiny, just as Einstein's theory "contains" Newton's mathematical theory of gravity on length scales where gravity is weak.

Can solve string theory near the event horizon (much larger than string scale) to determine the temperature of a black hole, get exactly Hawking's answer - deep connection between string theory and black holes.

Cannot yet solve for "singularity," but prospect to do so. Singularity would not be zero size and infinite density, but some behavior on the string length scale, not quantum foam, but some "stringy" nature.

Information fallen into black holes could be retained in string vibrations (or radiated away in Hawking radiation).

Reprise – Newton, Einstein, and String Theory

Newton had the concept of a "force" of gravity.

Einstein's theory had the concept of gravity as curved space.

When gravity is weak, the mathematical description of gravity in Einstein's theory is exactly the same as the mathematics of Newton. The concept is different.

String theory is a quantum theory. String theory has the concept of gravity as a quantum force for which the messenger particles are "gravitons" propagating in 10 spatial dimensions.

For safe distances from a singularity (where the full string theory would be needed and remains unsolvable), the mathematical description of gravity is exactly the same as the mathematics of Einstein. The concept is different than both Newton and Einstein.

Although string theory is a quantum theory, it is built on concepts of curved space.